Stability of Compressed Rods

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Abstract: The bend is called flat or straight if the plane of action of the load passes through the main central axis of inertia of the section. As a result of the construction, a plot of the distribution of the bending moment for each section of the beam was obtained, from which the greatest value is visible. Changes in normal and tangential stresses along the length of the beam depend on the values of transverse forces and bending moments. This study allows you to gain skills that will be used in project practice.

Key words: beams, axis, plane, curved axis, rod, beam, structure, cross sections.

In practice, the destruction of the rods can occur not only due to the loss of strength, but also from the fact that the rod does not retain its design shape. For reliable operation of the structure, in addition to ensuring its strength, it is necessary that all its elements are stable, under the influence of external loads, deformations must be within such limits that the nature of their work does not change. Stability is understood as the ability of the rod to maintain a state of equilibrium under the influence of small perturbations.

There are several research methods, such as the Euler method, the Lagrange method, the Karman method, the S.P.Timoshenko energy method, the Koiter method. In this article, the study will be conducted by the Euler method.

For a given design scheme of the rack (Fig. 1) with the following initial data: There are several research methods, such as the Euler method, Lagrange method, Karman method, S.P.Timoshenko energy method, Koiter method. In this article, the study will be conducted by the Euler method.

F=400 кН; l=5,0 м ; [σ]=13,3 кН/см the dimensions of the elements of the composite cross-section will be determined from the stability condition, the stability margin, the distance between the connecting bars from the condition of equality of local and general flexibility, the distance between the elements of the composite section will be determined.

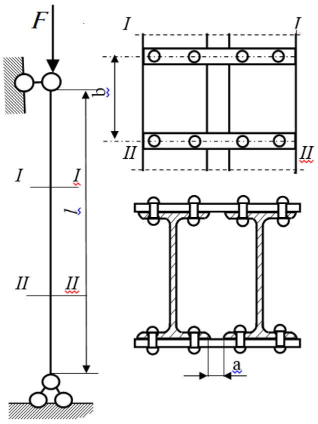

Fig.1. Design diagram of a composite cross-section rack

The selection of the cross section is made from the condition of stability of the column relative to the main central axis with a minimum moment of inertia of the cross-sectional area. For a given column, such an axis is the X-axis, since relative to the other main Y-axis, the moment of inertia can be changed by spreading or converging the branches of the column.

If the composite cross-section profiles can move apart relative to both main central axes, the minimum required moment of inertia of the cross-section is determined by the Euler formula for the critical force, adding to it the normative value of the stability margin coefficient for this material:

$$I_{\min} = \frac{F(\mu\, l)^2 [n_y]}{\pi^2 E}$$

where F -the effective load on the rod.

By the calculated value I_{min} taking into account the number of profiles, the required profile number is selected from the assortment, and then the stability of the column is checked..

The minimum required cross-sectional area is determined from the stability condition of the column:

$$\sigma_{\max} = \frac{F}{\varphi A} < [\sigma] \quad \Rightarrow \quad A \geq \frac{F}{\varphi[\sigma]}$$

where φ -the coefficient of longitudinal bending, which reduces the allowable stress in the rack when calculating stability.

There are two unknowns in the calculation formula at the same time: A and φ -Therefore, the calculation is carried out by the trial method.

The first calculation cycle .Setting the coefficient $\varphi = 0{,}5$

We find the required cross-sectional area of the column.

$$A = \frac{F}{\varphi[\sigma]} = \frac{400}{0{,}5 \cdot 13{,}3} = 60{,}15 \quad см^2$$

The share of one I - beam will have to

According to the tables of the I-beam assortment (GOST 8239-89), we choose I-beam

No. 24, which has

A=30,6см, $I_{x_C} = 2550 \quad см^4$

Calculate the moment of inertia of the I-beam relative to the x axis:

$$I_x = 2 \cdot I_{x_C} = 1730 \quad см^4$$

from inertia We find the smallest radius of the column cross section

$$i_x = \sqrt{\frac{2I_x}{2A}} = \sqrt{\frac{2550}{30{,}6}} = 9{,}128\,см$$

Calculating flexibility

$$\lambda_{\max} = \frac{\mu l}{i_{\min}} = \frac{1 \cdot 500}{6{,}57} = 76{,}103$$

Calculating flexibility

$$\lambda_{\max} = \frac{\mu l}{i_{\min}} = \frac{1 \cdot 500}{9{,}128} = 54{,}77$$

where μ is the length reduction coefficient, depending on the form of fastening.

According to the table of reduction coefficients of the permissible voltage reduction , we find the coefficient φ_1

$$\varphi_1 = 0{,}89 - \frac{0{,}89 - 0{,}86}{60 - 50}(54{,}77 - 50) = 0{,}875$$

We check the strength of the column

$$\frac{F}{\varphi_1 A} = \frac{400}{2 \cdot 30{,}6 \cdot 0{,}875} = 7{,}46 < 13{,}3$$

The overvoltage is

$$\frac{13{,}3 - 7{,}46}{7{,}46} \cdot 100\,\% = 7\% > 5\%$$

Which is unacceptable. The second calculation cycle. We accept the value of the coefficient

$$\varphi_2 = \frac{0{,}5 + 0{,}875}{2} = 0{,}6875$$

We find the required area

$$A = \frac{F}{\varphi[\sigma]} = \frac{400}{0{,}6875 \cdot 13{,}3} = 43{,}745 \quad см^2$$

The share of one I - beam will have to

$$\frac{43{,}745}{2} = 21{,}873 \quad см^2$$

According to the tables of the I-beam assortment (GOST 8239-89), we choose I-beam

No. 20, which has

$A = 26{,}8 \quad см^2 \quad I_{x_C} = 1840 \quad см^4$

Calculate the moment of inertia of the I-beam relative to the x axis:

$I_x = 2 \cdot I_{x_C} = 3680 \quad см^4$ We find the smallest radius of inertia of the cross section of the column:

$$i_x = \sqrt{\frac{2I_x}{2A}} = \sqrt{\frac{1840}{26{,}8}} = 8{,}28\, см$$

Calculating flexibility

$$\lambda_{\max} = \frac{\mu l}{i_{\min}} = \frac{1 \cdot 500}{8{,}28} = 60{,}386$$

According to the table of reduction coefficients of the permissible voltage reduction , we find the coefficient φ_3

$$\varphi_3 = 0{,}86 - \frac{0{,}86 - 0{,}81}{10}(60{,}386 - 60) = 0{,}858$$

We check the strength of the column

$$\frac{F}{\varphi_1 A} = \frac{400}{2 \cdot 26{,}8 \cdot 0{,}858} = 8{,}69 < 13{,}3$$

The overvoltage is

$$\frac{13{,}3 - 8{,}69}{8{,}69} \cdot 100\,\% = 5{,}2\% > 5\%$$

Which is unacceptable. The third calculation cycle. We accept the value of the coefficient

$$\varphi_4 = \frac{0{,}6875 + 0{,}875}{2} = 0{,}772$$

We find the required area

$$A = \frac{F}{\varphi[\sigma]} = \frac{400}{0{,}772 \cdot 13{,}3} = 38{,}9 \quad см^2$$

The share of one I - beam will have to

$$\frac{38{,}9}{2} = 19{,}45 \quad см^2$$

According to the tables of the I-beam assortment (GOST 8239-89), we choose I-beam
No. 16, which has

$$A = 20{,}2 \quad см^2 \; I_{x_C} = 873 \quad см^4$$

We find the smallest radius of inertia of the cross section of the column

$$i_x = \sqrt{\frac{2I_x}{2A}} = \sqrt{\frac{2 \cdot 873}{2 \cdot 20{,}2}} = 6{,}57\, см$$

Calculating flexibility

$$\lambda_{\max} = \frac{\mu l}{i_{\min}} = \frac{1 \cdot 500}{6{,}57} = 76{,}103$$

According to the table of reduction coefficients of the permissible voltage reduction , we find the coefficient φ_5

$$\varphi_5 = 0{,}81 - \frac{0{,}81 - 0{,}75}{10}(6{,}103) = 0{,}773$$

We check the strength of the column

$$\frac{F}{\varphi_5 A} = \frac{400}{2 \cdot 20{,}2 \cdot 0{,}773} = 12{,}8 < 13{,}3$$

The under - voltage is

$$\frac{13{,}3 - 12{,}8}{12{,}8} \cdot 100\% = 3{,}8\% > 5\%$$

There is no I-beam with a more suitable cross-sectional area in the assortment. Therefore, we finally accept I-beam No. 16.

The stability margin is determined by the appropriate formula, having previously calculated the critical voltage.

$$F_{кр} = \frac{3{,}14^2 \cdot 2 \cdot 10^4 \cdot 58{,}6}{(1 \cdot 500)^2} = 46{,}22\, кН \quad F_{кр} = \frac{\pi^2 \cdot E \cdot I_{\min}}{(\mu \cdot l)^2}$$

Column flexibility $\lambda_{\max} = 76{,}103$ Calculate the critical voltage

$$\sigma_{кр} = \frac{\pi^2 \cdot E}{\lambda^2} = \frac{3{,}14^2 \cdot 2 \cdot 10^4}{76{,}1^2} = 34\, \frac{кН}{см^2} = 340\, МПа$$

We find the coefficient of stability margin

$$n_y = \frac{\sigma_{кр}}{\sigma} = \frac{34}{9,9} = 3,43$$

where

$$\sigma = \frac{F}{A} = \frac{400}{2 \cdot 20,2} = 9,9\,\frac{кН}{см^2} = 99\,МПа$$

normal compression stress of the column.

if the flexibility is less than the limit <100, then the empirical formula proposed by Yasinsky is used to calculate the critical force:

For steel rods of building structures $[n_y] = 1,7 \div 2,0$

for wooden $[n_y] = 3,0$ cast iron $[n_y] = 5,0$ for elements mechanical engineering structures $[n_y] = 3,5 \div 5,0$

The distance between the connecting bars is determined from the conditions that the flexibility of a separate branch between the connecting bars should not exceed the flexibility of the column as a whole:

$$\lambda_b = \lambda_{\max}$$

The section of the column between the slats is conditionally considered pivotally supported. Then we get

$$b = i_{\min,b} \cdot \lambda_{\max}$$

where $i_{\min,b} = 1,7\ см$ the minimum radius of inertia of the I-beam is taken from the assortment.

$$b = 1,7 \cdot 76,103 = 129,4\ см$$

Let's determine the distances between the elements of the composite section.

In order for the rack to be equally stable in the main planes of inertia, it is necessary to fulfill the condition:

$$I_x = I_y$$

$$2I_x = 2\left[I_{y_C} + \left(\frac{b}{2} + \frac{a}{2}\right)^2 A\right]$$

For I-beam No. 16 $I_{x_C} = 873\ см^4$ $I_{y_C} = 58,6\ см^4$ $b = 8,1\,см$ $A = 20,2\ см^2$

$$2 \cdot 873 = 2\left[58{,}6 + \left(\frac{8{,}1}{2} + \frac{a}{2}\right)^2 \cdot 20{,}2\right]$$

$$\left(\frac{8{,}1}{2} + \frac{a}{2}\right)^2 = 40{,}316 \quad \Rightarrow \quad b = 4{,}59\ см \approx 5\ см$$

In this work, stability calculations were made, the dimensions of the elements of the composite section were assembled, the distance between the connecting bars and the distance between the elements of the composite section were determined.

The values of critical loads can be obtained in the form of formulas such as the Euler formula for rods of variable cross-section and under the action of several compressive forces.

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